

# **The Payoff From Public Agricultural Science and Technology**

**Luther Tweeten\***

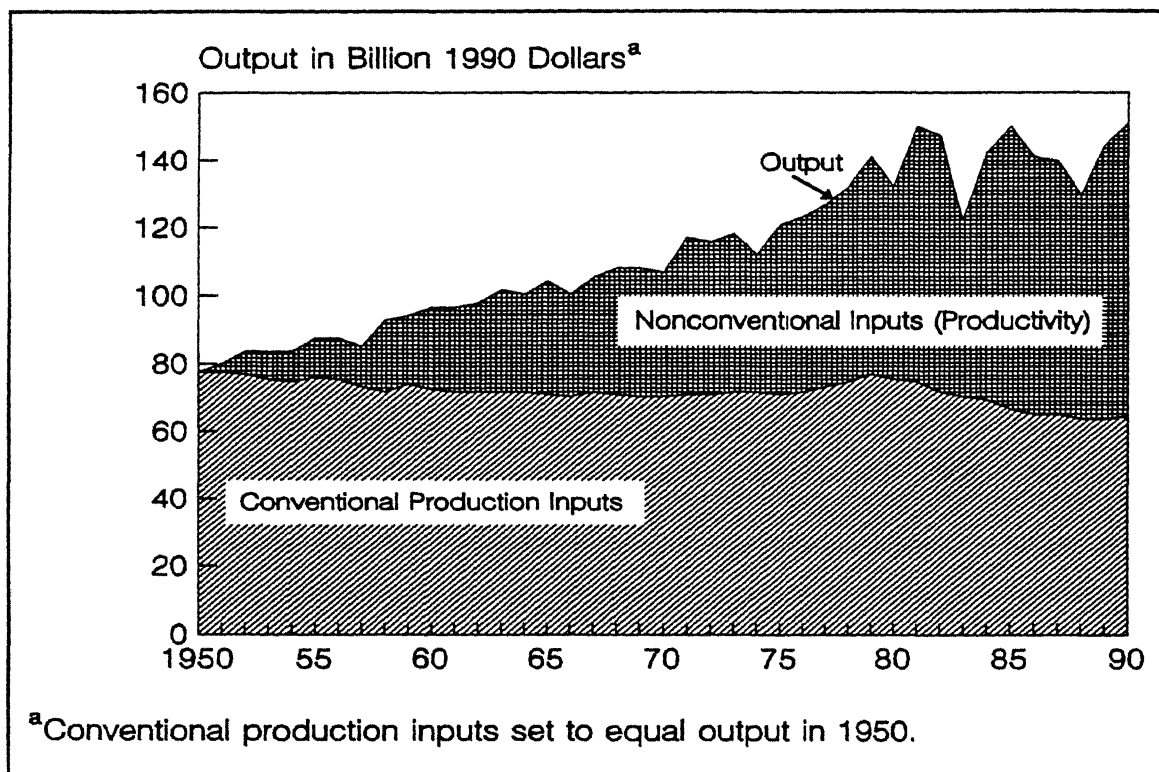
The stalled American economy can revive only by returning to first principles: by investing in environmentally sound, high economic payoff activities. Public agricultural science and technology is such an activity.

The food and fiber industry is the nation's largest, accounting for 15% of the domestic economy in 1992. The farm sector, accounting for only one-tenth of the food and fiber industry, is of interest for several reasons. Farms are too small to supply their own science and technology. Agriculture has been a special focus of land grant colleges of agriculture and land grant universities with spectacular payoff in low-cost sources of food and fiber. Agriculture contributes mightily to our economy by earning foreign exchange, employing 2% of the nation's resources but supplying 12% of the nation's exports.

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Agriculture is a growth industry. Farm output was \$151 billion in 1990, double that in 1950 (Figure 1). Yet farmers used 17% less aggregate conventional production inputs in 1990 than in 1950 (Figure 1)! Nonconventional inputs measured by productivity gains since 1950 alone accounted for 57% of farm output in 1990 while conventional inputs accounted for only 43%.



**Figure 1. Sources of Farm Output Growth from 1950 to 1990.**

Source: Basic data from USDA. Nonconventional inputs gains shown only for 1950 to 1990 came in no small part from R and E conducted *before* 1950.

The spectacular agricultural productivity gains did not happen by chance. They were the product of a deliberate investment in *nonconventional inputs* variously referred to as

knowledge, science and technology (S and T), research and extension (R and E), and education.<sup>1</sup> At issue are the payoffs to consumers, the environment, and the nation from nonconventional input investments. This report documents these payoffs.

### *Payoff to Consumers \$196 Billion in 1990 Alone*

The actual farm food and fiber output of 1990 would have required 2.3 times as much production input if produced with 1950 technology. This would have added \$196 billion or 23% to consumers' food and fiber costs. In relative terms, the major losers from less agricultural productivity would be low income people who spend a high proportion of their income for food.

### *Payoff to Environment and Natural Resources*

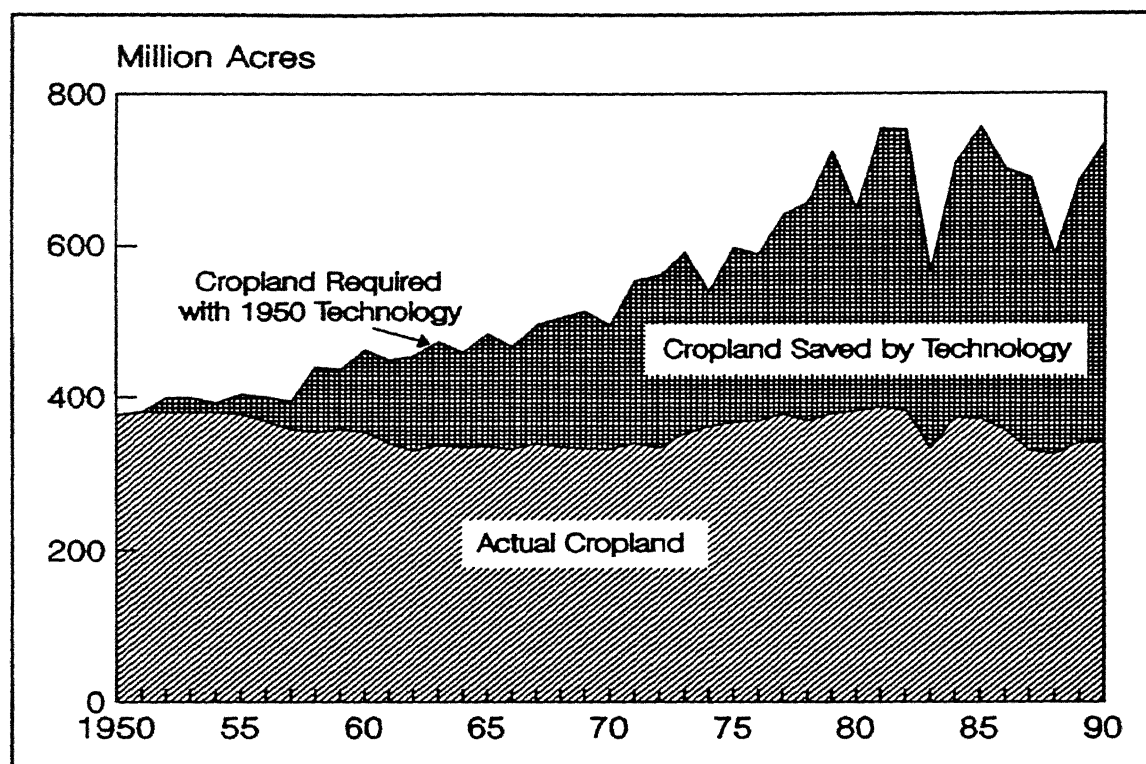
Crop output of 1990 would have required 734 million acres if produced with 1950 technology (Figure 2). That's 393 million acres more than the 341 million acres harvested in 1991.<sup>2</sup>

Several problems would be apparent in the absence of high farming efficiency. The nation doesn't have 393 million additional acres of prime farmland. Expansion of crops to fragile soils would sharply raise soil erosion.

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<sup>1</sup>The unstable year-to-year contribution to output from nonconventional inputs apparent in Figure 1 arise because weather is included as a nonconventional input.

<sup>2</sup>It may be argued that higher food prices attending less productivity would reduce demand for food and land. On the other hand, the data in Figure 2 did not include the impact of less productivity in the livestock sector which would add to demand for land to supply livestock feed.



**Figure 2. Acres Required with 1950 Technology, 1950-1990.**

Source: Basic data from USDA.

Improved farming practices and technologies markedly reduced soil erosion. Based on data reported in the 1938 *Yearbook of Agriculture* and the 1987 Conservation Needs Inventory, sheet and rill erosion fell from over 3.5 billion tons in 1938 to 1.6 billion tons in 1987, or over 50%.

Since 1987, rates have dropped further from expansion of conservation tillage, the Conservation Reserve Program, Conservation Compliance, and other practices. Soil erosion

from water today is about one-third the rate of the 1930s.<sup>3</sup> Thus erosion rates today might be six times those of the 1930s in the absence of improved yields and farming practices -- considering both additional acres that would need to be cropped and the higher erosion rates on all acres. Improved technology was the major source of reduced erosion not only because fewer acres needed to be cropped but also because it improved conservation practices.

In the future, cropland will continue to be lost to erosion and to nonfarm uses. According to several studies (see Tweeten, 1989, pp. 268, 269), continuation of erosion at current rates would reduce agricultural productivity 5% in a century. Currently, about one in a thousand acres of prime farmland annually is converted to urban and built-up uses. Persistence of this rate could lose 10% of prime farmland in a century.

Cropland harvested fell -.25% per year on average from 1950 to 1990, a loss if continued of 25% per century. This rate of decline was the result of reduced demand for land for farming as well as of soil erosion and urban development. Current productivity gains of 1.4% per year offset in 10 years the 5% loss to erosion and 10% loss to urban and other developmental uses of a century! Fortunately, these losses to erosion and urban development are declining. Science and technology can continue to substitute for future loss of cropland, but must not be taken for granted. S and T do not justify abdication of conservation.

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<sup>3</sup>This estimate is conservative. Brown (p. 397) concluded that the Conservation Reserve and Conservation Compliance programs alone "...will have reduced topsoil losses from cropland by two-thirds in a 10-year period" from 1986 to 1995.

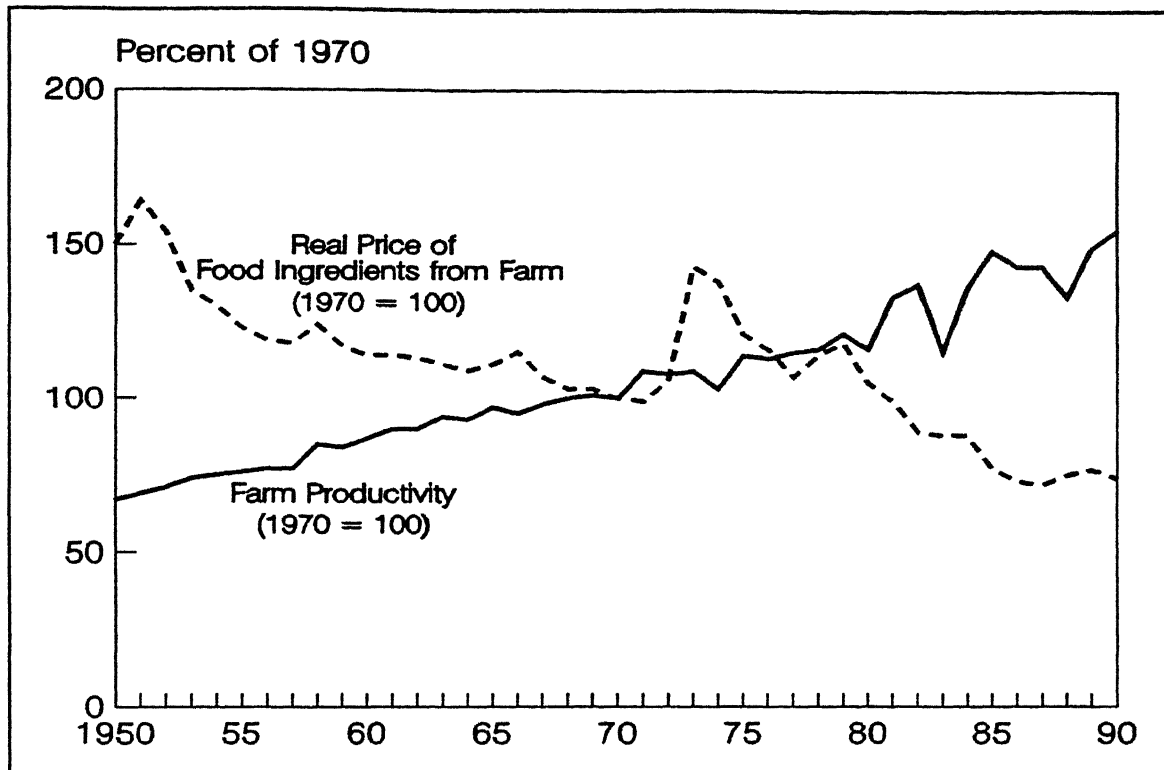
Natural resource limits in addition to land also must be confronted. Global petroleum reserves are projected to last 50-75 years and phosphate fertilizer reserves 90 years at current levels of use (Tweeten, 1979, Ch. 9). As supplies become short, prices will rise, use will slow, and new reserves and substitutes will be found. But a wise policy is to invest in agricultural and other technology to substitute for and reduce demands on petroleum, phosphate, land, water, and air resources. Failure to keep options open by investing in agricultural science and technology would be shortsighted indeed. Miscalculation would be difficult to correct later because of the long lag between investments and payoffs from science.

### *Payoffs to the Nation*

Figure 3 illustrates how rising farm productivity has been translated into lower real food costs. The figure reaffirms results shown in earlier figures. These obvious benefits must be balanced against costs of raising productivity to determine net payoffs.

Huffman and Evenson and Braha and Tweeten summarize a large number of previous estimates and provide their own estimates of returns to agricultural research, extension, and education. As expected, estimated returns differ among studies, geographic areas, enterprises, functions (research R, extension E, etc.), and analysts. Estimates by Braha and Tweeten (p. 11) are typical of other studies. Their results can be expressed equivalently in various ways:

1. A 45% internal rate of return in the 1980s for all U.S. crop and livestock public R and E. This means that the public could have broken even if it had paid a 45% interest rate on funds invested in agricultural R and E.



**Figure 3. Farm Productivity and Food Prices, 1950-1990.**

Source: Basic data from USDA.

2. Each \$1 invested in agricultural research and extension returned approximately \$10 (undiscounted) over the 16-year typical life of technology produced by R and E.
3. The \$10 of farm output generated by \$1 of R and E is \$4.74 after discounting output over time at a 10% interest rate to represent the opportunity cost (alternative use value) of funds.

These favorable payoffs have held up over time based on numerous studies.

In a recent study, Huffman and Evenson (Table 9.1) estimated the internal rate of return on aggregate agricultural research and development for 1950-82. Rates were as follows:

- Public sector: 41%
- Private sector: 46%
- Public extension: 20%
- Farmers' schooling: 40%.

Few public or private investments pay better. Indeed, typical stock market investments pay about a 10% return.

#### *Why Not Leave Research and Development to the Private Sector?*

We don't know much about payoffs to the private sector from R and D but fragmentary available evidence (such as the 46% internal rate of return estimated by Huffman and Evenson) suggests favorable returns. Real outlays for agricultural research in the private sector increased on average by 3.2% annually in the 1980s and in 1990 totaled \$4.21 billion.<sup>4</sup> Real public research outlays in the 1980s were virtually static and totalled only \$2.21 billion in 1990 -- about half the private level. Total real public extension outlays also were stagnant in the 1980s. With total real outlays stagnant, public research and extension outlays *per unit of farm output* fell sharply in the 1980s primarily because of a large fall in federal outlays. Federal real research outlays dropped from \$683 million (1990

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<sup>4</sup>Data on R and E outlays here and elsewhere in this report are from Huffman and Evenson.



dollars) in 1980 to \$614 million in 1990. Federal extension outlays dropped from \$413 million (1990 dollars) in 1980 to \$355 million in 1990.

For several reasons the public would be unwise to rely solely on the private sector for future agricultural research and extension:

1. Numerous agricultural technologies and practices with high social payoff have low payoff to private firms. Private firms will not supply enough such research. Examples are basic science, pest-resistant crop varieties that can be reproduced by producers, and soil-saving cultural practices. Much high-payoff science and technology now making the private sector's applied research and production efficient will not be performed by the private sector in the absence of public support.
2. Nearly half of private sector research is oriented to creating differentiated private food brands and the like rather than to increasing productivity of the food and fiber system and protecting the environment.
3. An unknown but probably considerable portion of the buildup of private research in the 1980s was in anticipation of high payoffs from biotechnology which have not materialized. Many private research firms have failed, consolidated, or sharply curtailed efforts to develop food and fiber productivity-enhancing technologies.
4. Many agro-ecosystem niches require basic and applied adaptive research in new plant varieties, pathology control, and environmental protection. Without

public R and E, these niches may be bypassed by technology from the private sector.

5. Reduced *federal* funding of agricultural science and technology is especially troubling. It is typical for one-third of the benefits of an agricultural technology developed in one state to spill over to help the agriculture of other states. *Virtually all of the benefits of agricultural R and E eventually are passed to consumers* -- most outside the state developing the new technology. This spillover means that what is unprofitable for a state may be highly beneficial to the nation. Much can be said for distributing funds to states: it provides base support for addressing problems unique to individual states and encourages healthy competition among states to develop technology. The continuing finding by analysts, many not at land grant universities, of high payoffs from R and E testifies to the success of past efforts.

A recent study by Huffman and Just found a high payoff from federal base funding such as Hatch funds with considerable discretion in choice of project left to the researcher. They (p. 20) concluded from detailed empirical analysis that

Increasing the share of State Agricultural Experiment Station funds obtained from federal contracts and grant research reduced the productive efficiency of research expenditures and/or shifted the focus of scientific discoveries and technology developments away from innovations that raise local agricultural productivity.

There are risks in tampering with a proven system that has made American agriculture the envy of the world and an important source of economic betterment for the nation.

### *No Basis for Complacency*

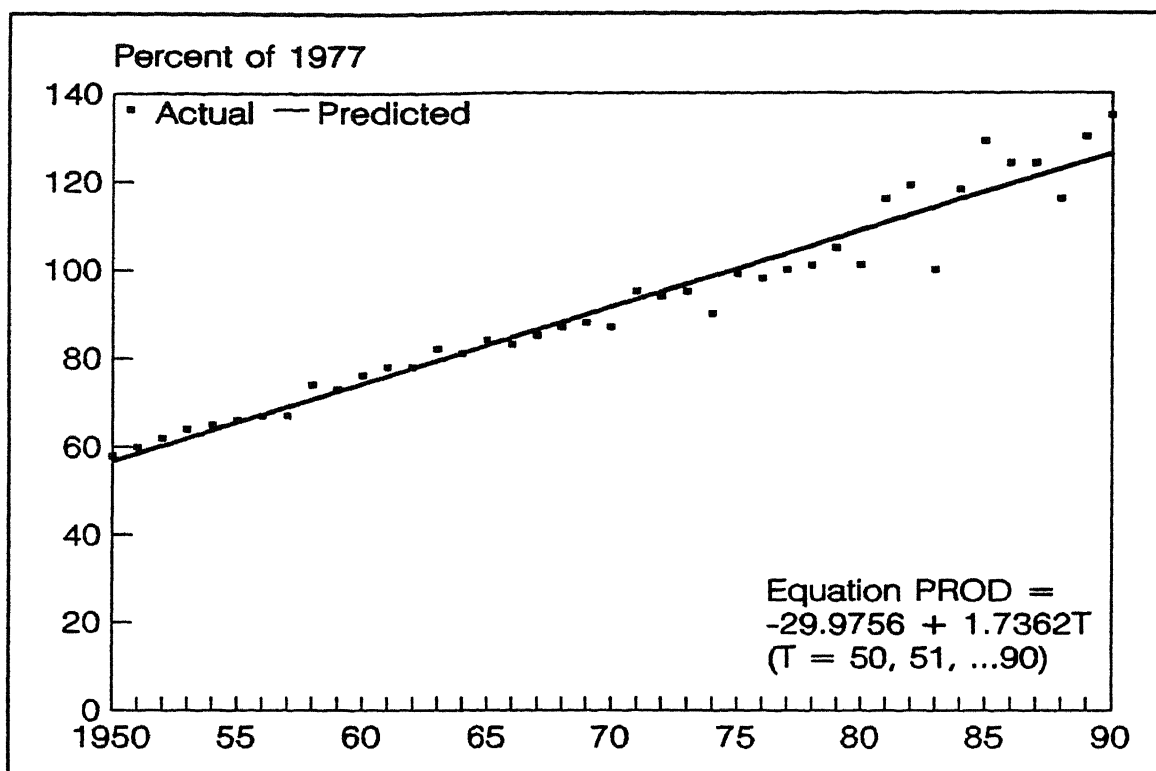
The spectacular productivity gains underlying Figure 1 and shown in Figure 4 provide no basis for complacency. A straight line fits the actual historic data about as well as any -- as apparent in Figure 4.

Two observations are especially important regarding that trend:

1. Productivity appears to be getting more unstable from year to year. That variation is due mostly to weather. There is no empirical evidence that modern technology is more sensitive to weather and pestilence than traditional technology.
2. The second observation is that, although absolute gains in productivity are not slowing, the percentage rate of gain is falling. Percentage rates of increase in productivity from the trend line shown in Figure 3 are as follows:

Year	Percent Annual Increase
1950	3.1
1960	2.3
1970	1.9
1980	1.6
1990	1.4

The annual percentage trend rate of gain in 1990 was less than half that in 1950!



**Figure 4. Actual and Predicted Aggregate U.S. Farm Productivity, 1950-1990.**

Source: Basic data from USDA.

If productivity increases supply at a slower rate than the increase in demand, the real price of farm ingredients of food will rise.<sup>5</sup> In 1990 the trend rate of growth in U.S. domestic and foreign aggregate demand for food and fiber was 1.5%, just over the rate of increase in supply (productivity) shown in Figure 3.<sup>6</sup> Demand on average is expected to

<sup>5</sup>Real prices currently average 51% those in the 1910-14 period, a widely used parity standard. Consumers are better off as illustrated in Figure 1, but farmers are not worse off. Productivity increased 3.35 times from 1910-14 to 1990, implying that farmers needed a price only 1/3.35 or 30% of the 1910-14 average to maintain resource earnings. Thus the 30% price needed compared to 51% actual means that real price or parity adjusted for productivity increased 70% from 1910-14 to 1990!

<sup>6</sup>Growth in population was 0.9%, in real income per capita 1.5%, and in exports 3%. If 25% of farm output was exported as in 1990 and an income elasticity of domestic demand of 0.1.

increase 1.4% annually in the 1990s. If productivity growth continues to slow, real food prices will begin to rise.

The conclusion is reason for concern but not for panic. New technologies await. Recombinant Bovine Somatotropin (rBST) is an example. Nonconventional inputs currently increase output about \$2 billion per year. After adoption, rBST will add at most \$1 billion to nonconventional input benefits each year (Tweeten, 1991). Thus 20 rBST technology-equivalents would need to be adopted in the 1990s simply to maintain productivity gains at the 1990 rate. Twenty such breakthroughs from biotechnology are not anticipated. More mundane sources of productivity must supplement such as improved crop varieties, greater feed efficiency, effective control of pests, and more efficient use of natural resources. Public *and* private research efforts will be essential, with the public sector especially prominent in providing basic and other "public good" research while the private sector will be prominent in applied research and development.

Additional factors to keep in mind are the high maintenance costs of today's technologies. Crops lose their pest resistance and farming practices become obsolete. New sustainable agricultural systems beckon, but much basic science and technology will be required to simultaneously raise output while reducing environmental and other costs. Many current environmental measures require difficult tradeoffs. Some reduce output to protect the environment. Others, for example, conservation tillage can require more herbicides, some of which may pollute groundwater supplies to save soil. On the other hand, organic farming can require more mechanical tillage, increasing soil loss. Investment in science and technology is essential to make these tradeoffs less onerous.

## References

- Braha, Habtu and Luther Tweeten. September 1986. Evaluating past and prospective future payoffs from public investments to increase agricultural productivity. Technical Bulletin T-163. Stillwater: Agricultural Experiment Station, Oklahoma State University.
- Brown, Lester. November-December 1991. A global competition for land. *Journal of Soil and Water Conservation*, pp. 394-397.
- Huffman, Wallace and Robert Evenson. June 1992. *Science for Agriculture*. Ames: Department of Economics, Iowa State University.
- Huffman, Wallace and Richard Just. August 1992. Structure, management, and funding of agricultural research in the United States: Direction and likely impact. Ames: Department of Economics, Iowa State University.
- Tweeten, Luther. 1991. The costs and benefits of bGH will be distributed fairly. *Journal of Agricultural and Environmental Ethics* 4:108-120.
- Tweeten, Luther. 1989. *Farm Policy Analysis*. Boulder, CO: Westview Press.